A Network-Centric Enterprise Service for Mediation and Interoperability: The Dynamic Operational Object Registration Service (DOORS)

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ABSTRACT

Warfighters conducting joint and coalition task force operations and inter-governmental agency operations supporting homeland security must interoperate with C2/C4I systems that possess disparate mapping/visualization and information management infrastructures. These C2/C4I systems are generally built upon dissimilar data representations and stovepipe interfaces. To achieve information superiority while engaged in such operations, commanders must transform component C2/C4I system data into interoperable information and shared knowledge, making the result available for exchange to multiple levels and nodes bases upon need and choice. This level of interoperability is critical for geo-spatially and temporally registered *operational object* information that comprises situation understanding aspects of a common operational picture, which also extends to supporting "drill down" information. SAIC's Dynamic Operational Object Registration Service (DOORS) was developed in the anticipation that a properly conceived C2/C4I vocabulary of domain knowledge representation, supported by an ontology-driven adaptive system, and employing meta-data based translation services (mapping of data from each participating system to a common representation) will provide the requisite basis for a network-centric enterprise data mediation service that addresses current interoperability challenges. DOORS provides the mechanism to exchange interoperable information for joint/combined task force operations according to a register-publish-subscribe metaphor that reflects the commander's information exchange requirements.

A NETWORK-CENTRIC ENTERPRISE SERVICE FOR MEDIATION AND INTEROPERABILITY: THE DYNAMIC OPERATIONAL OBJECT REGISTRATION SERVICE (DOORS)

INTRODUCTION

Achieving interoperability amongst the vast assortment of systems used for Command and Control (C2) and Command, Control, Communications, Computers and Intelligence (C4I) supporting the warfighter's decision-making process remains the most critical problem facing military operations.

Historically, this problem has been approached by codifying and developing pair-wise system-to-system interfaces consisting of highly structured and inflexible data exchanges via messaging or remote procedure calls (RPCs), or worse, by utilizing some lesser means such as semi-automated or manual data transfer. As the number of systems brought into play during today's joint and combined force operations proliferates, this predicament is made worse, resulting in an increasingly complex tangle of information exchange requirements – the so-called *n^2 problem*.

This interoperability problem is most pronounced when considering the situation awareness (SA) and situation understanding (SU) elements of C2/C4I functional architectures, which strive to represent geo-spatially and temporally referenced information critical to the decision-making process. Often referred to as a Common Operating Picture (COP), this capability is intended to provide a coherent, consistent, relevant, and unambiguous view of the *battlespace infosphere* containing the information required to achieve decision superiority in a timely fashion. However, the efficient construction of a true COP has been hindered by fragmented conceptions of COP domain representations, and the furtherance of individually-developed evolutionary and legacy "stovepipe" systems.

Past approaches to this interoperability challenge have focused upon providing standardized, underlying representations for all participating C2/C4I systems; that is, a common object/data model or database. If implemented uniformly, this tightly coupled method allows for the synchronization of information between all sources and sinks, providing a unified view of the represented domain and preserving data and transactional integrity. While progress has been made using multiple variations of this methodology, funding and schedule constraints inherent in the acquisition process have served to hinder the resolution of the interoperability problem via the migration of C2/C4I systems to common models. Further difficulties with this approach include:

- Development and maintenance of common, standardized C2/C4I models are exhaustive undertakings, prone to colossal management schemes.

Interoperability fissures will be introduced whenever domain gateways are required.

- Common, standardized C2/C4I models evolve by nature, and it is prohibitively expensive for all participating C2/C4I systems to continually modify/update. *Interoperability fissures will be introduced whenever baseline divergence occurs.*

- Common, standardized C2/C4I models do not allow for the rapid integration of non-participating C2/C4I systems. *Interoperability fissures will be introduced whenever non-conformant players arrive on the scene.*

- Elements within the C2/C4I domain defy common, standardized representation. *Interoperability fissures will be introduced whenever vocabulary mismatch occurs.*

The current emphasis on defense transformation to network-centric warfare (NCW) systems and network-centric enterprise services (NCES) that draw upon a global information grid (GIG) of available knowledge demands a highly interoperable fabric of exposed information, services, and systems.

More recent developments aimed at providing interoperability amongst participating C2/C4I systems have shifted the focus from object/data standardization to mediation (or integration) via transformational mapping techniques. In this scenario, a common object model is introduced as a instantiated NCES that mediates the differences in semantic representations between participating system-specific schemas, by establishing the map between the participant system's local vocabulary and a common C2/C4I vocabulary resident within the mediation service (thereby acting as a semantic gateway between disparate representations). Initiatives such as the Office of the Secretary of Defense's (OSD) Family of Interoperable Pictures (FIOP), the Joint Chiefs of Staff's (JCS) Situational Awareness Data Interoperability (SADI) project, and the JCS Joint Warfighting Capabilities Assessment (JWCA) Joint Task Force (JTASK FORCE) C2 Interoperability Study, along with related agency/service programs, such as DISA's DII COE/NCES, GCCS/Joint C2 System, and DOD Data Emporium/eXtensible Markup Language (XML) Registry have been pursuing similar directions.

Semantic mapping can be static, where system developers use configuration applications such as ontology builders to collect and explicitly transform their systems' object model into that of the mediation service; or, dynamic where an expert system and knowledge base assists in varying degrees of automatic mapping upon the registration of new participant system vocabularies. These loosely coupled methods leverage semantic representation efforts related to common models, yet are targeted at providing interoperability "glue" rather than forcing conformance upon multiple participant system underlying representations. Further, there need not be a single type of mediation NCES; sage governance can give rise to multiple, interoperable mediation services focused upon communities of interest (COI). Benefits of the mediation NCES approach include the following:

- The constituent semantic mappings and resultant ontology of the mediation NCES are reusable. Systems developers provide their system-specific translation maps once, and then the participant system can interoperate via the mediation NCES with all other participant systems. *Seamless interoperability will be fostered despite local-local vocabulary mismatches.*

- The mediation NCES provides a reductive interface, thus systems developers may provide their system-specific translation maps via one interface, and then the participant system can employ the mediation NCES for all other required interfaces. *Seamless interoperability will be fostered via simplified, efficient software development efforts, and promote baseline convergence.*

- The mediation NCES provides a flexible model for registering local vocabularies for local domains, providing a plug-n-play modular interface. This enables the inclusion of new participant systems into the mediation scheme via ontology building and semantic mapping via declaration. Participant systems are free to provide either as much or as little exchange of their information as warranted. *Seamless interoperability will be fostered via focusing upon shared exchange of truly common objects.*

- The mediation NCES allows for local vocabularies for local domains, allowing participant systems to isolate their schema from changes induced by invasive interoperability measures and evolving standards. *Seamless interoperability will be fostered via focusing upon the exchange of truly common, shared objects.*

TECHNICAL APPROACH

System Concept

DOORS addresses the interoperability problem by providing a mediation NCES categorized by three operational directions:

1. Translation of C2/C4I system-specific objects at the interface boundary into "*Interoperable Information"* according to accepted standards for common representation.
2. Exchange of *"Interoperable Information"* for joint/combined task force operations according to a register-publish-subscribe metaphor that reflects the commander's information exchange requirements.
3. Assured delivery encompassing reliable, near real-time dissemination of DOORS-exchanged information in task force-focused operational networks.

Once fully realized, the DOORS program would function as an Infrastructure NCES existing within the Global Information Grid (GIG). Each disparate participant system (a DOORS participant system is defined as a warfighter's C4ISR, C3I, C2, M&S, or other system of interest which has implemented a DOORS-conformant interface) registers information it will provide to other participant systems. The DOORS Service enables information exchange by providing a mediation and brokering layer between disparate systems, translating from a system-specific set of warfighter objects to a

common domain knowledge representation or *ontology* for dissemination to interested parties and subsequent translation into the native formats of downstream participant systems connected to the DOORS NCES. DOORS will allow tailored views of information to be shared among users with disparate C2 systems operating within a seamless task force environment, providing the commander of the task force the ability to visualize and drill down into information supplied by DOORS-enabled C2 systems employed by his component commanders during operations. The DOORS NCES will leverage existing dissemination and replication mechanisms within the network; and incorporate an inherent capability to ensure reliable delivery of interoperable information. Three technology initiatives will support the DOORS NCES:

1. Formation of an XML-based ***C2/C4I Vocabulary or Common Ontology*** encompassing known standards for representation of C2/C4I domain knowledge.
2. ***Metadata-based Ontology Translation*** between disparate C2 systems via ***Semantic Mapping*** techniques, utilizing the evolving body of knowledge known as the Semantic Web, including the DARPA Agent Markup Language (DAML) and Ontology Inference Language/Ontology Interchange Layer (both OIL => DAML+OIL), the Resource Description Framework (RDF), etc.
3. Exploitation of best of breed ***Distributed Information Architectures*** for interoperability, scalability, and dissemination: Hybrid Peer-to-Peer object exchange models, Web Services, etc.

Once operational on the GIG, participant systems with DOORS-compliant interfaces can register with DOORS, publishing objects [e.g. map overlays containing symbols] and providing them to the DOORS Web Service [i.e. server] for advertisement to other participant systems. Operators throughout the network may then use a DOORS Client Agent resident on their system to access these objects until the provisioning system either denies access to the objects or opts to delete them from the DOORS Web Service.

By introducing the above concepts, DOORS allows multiple, disparate systems with distinct architectures [i.e. presentation/mapping, business logic information management, and data persistence component subsystems, etc.] to exchange information via a single interface rather than construct and manage *N* multiple bi-lateral interfaces, i.e. an additional interface for each system it is required to exchange information with. The DOORS NCES acts as a *gateway* that translates system-specific information from client-side agents into its C2/C4I vocabulary (or common ontology) and publishes the results for subscribers to retrieve upon notification by the service. Assuming the DOORS Web Service is available throughout the GIG network, this has the affect of reducing N^2 interfaces, thereby alleviating network communication by trunking and routing system-to-system information exchange through the DOORS NCES. **Figure 1** illustrates this principal.

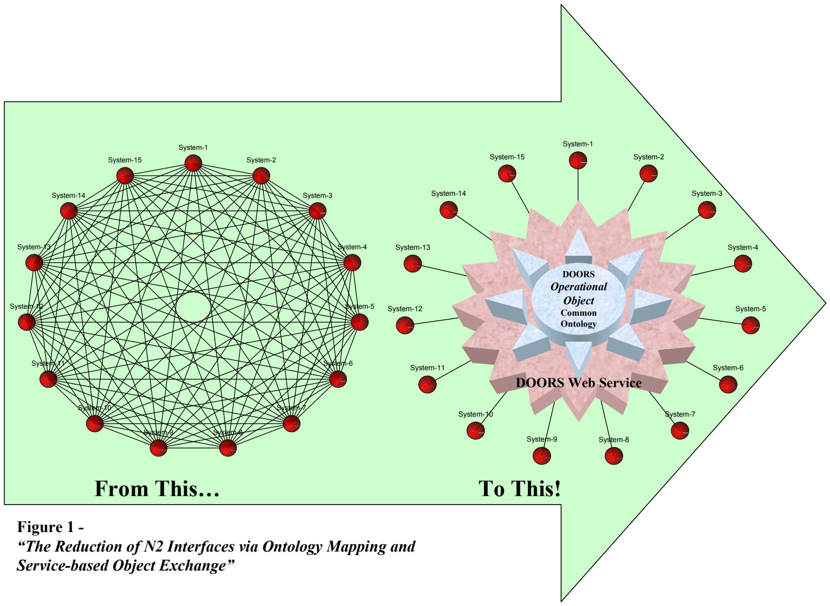


Figure 1 -
"The Reduction of N2 Interfaces via Ontology Mapping and Service-based Object Exchange"

C2/C4I systems are producers and consumers of a wide variety of operational object categories and will naturally register, publish, and subscribe to those objects that have a representation closely aligned with their own internal data structures. DOORS employs semantic mapping, therefore object exchange can occur between disparate system-specific representations as well as a variety of object formats and standards. Thus, the DOORS NCES provides data mediation between systems created for a range of purposes or encompassing diverse standards. For example, operational C2 systems may be driven by modeling & simulation systems, a JVMF message provided by one system may be translated into an MIL-STD-2525 overlay on another. The variety of object exchange solutions addressed by the DOORS technical approach to schema translation is illustrated in **Figure 2**.

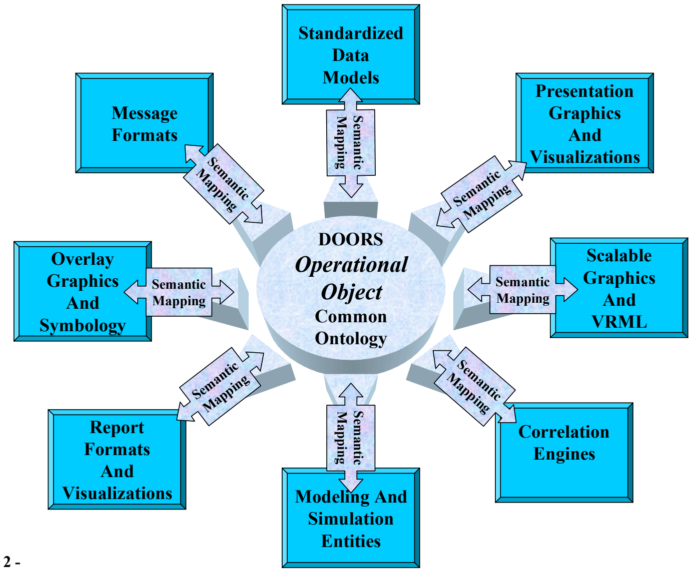


Figure 2 -
"The Conceptual Context for Object Exchange"

System Architecture

A top-level DOORS systems architecture is illustrated in **Figure 3**. Residing within the cloud representing the GIG network and other NCES infrastructure components, the DOORS Web Service may be federated to leverage the synchronization and replication of published objects in accordance with *"power to the edge"* concepts such as ***Task/Post/Process/Use (TPPU)*** network-centric operations described by DOD's Assistant Secretary of Defense for C3I.

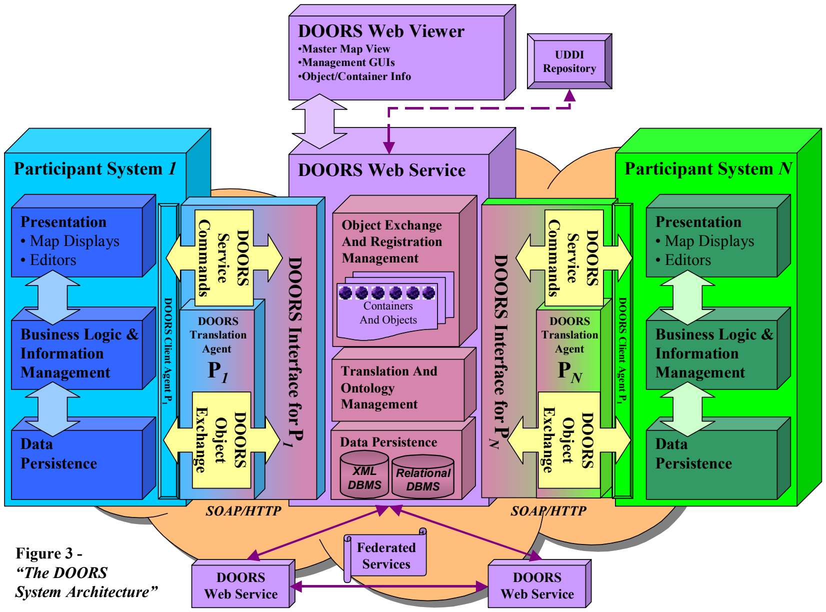


Figure 3 -
"The DOORS System Architecture"

DOORS was conceived as a network-centric enterprise service and embraces Web Services for its technological underpinnings as depicted in **Figure 4**, building upon the *Sun Microsystems's Java/J2EE*^{TM} architecture with Simple Object Access Protocol (SOAP) interfaces described by the Web Service Definition Language (WSDL). Optionally, the DOORS NCES may be advertised on the GIG via a UDDI repository. For more information about Web Services and its component specifications, please see the World Wide Web Consortium (W3C®) at http://www.w3c.org/.

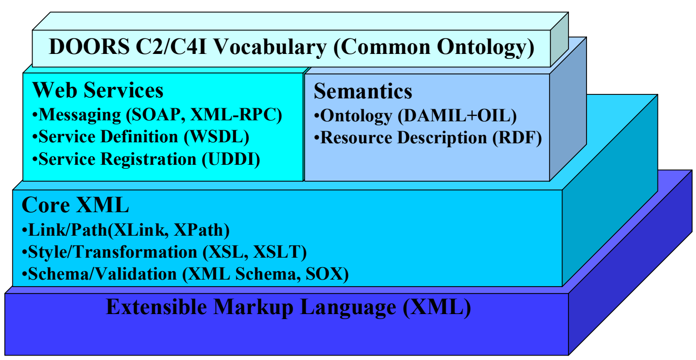


Figure 4 -
"Use of XML Technologies/Specifications in DOORS "

Each type of participant system is assumed to have a unique combination of components spanning the presentation (map displays, editors, report generators), business logic/information management (n-tier applications, common, and support services), and data persistence (databases, file systems) architectural layers that adhere to well-defined yet potentially dissimilar internal representations of information. Therefore, each participant system is required to create and host a system-specific **DOORS Client Agent**; This agent provides the interface connection to any public interface offered by the participant system, whether it be an application programmer's interface (API), a database connection object, or other structured content readable by the DOORS Client Agent such as a delimited file or XML document. The agent may bind to any technology required to interface with the participant system, yet must possess the SOAP/XML interface to subscribe to the DOORS Web Service. The system-specific **DOORS Translation Agent** provides schema translation according to the semantic mapping between the participant system's knowledge representation and the DOORS common ontology or C2/C4I Vocabulary. For each **Participant System (*1-N*)**, DOORS proffers a SOAP/XML interface comprised of two constituent sections:

- **DOORS Service Commands** – for registration, notification, flow of control, and other system-level commands common to all DOORS Client Agents.
- **DOORS Object Exchange** – for exchange of operational object information, including attributes and methods defined by a system-specific DOORS Translation Agent.

Within the DOORS Web Service proper are the following major subsystems:

- **Object Exchange and Registration Management** – for management of the registration, publish, and subscribe mechanisms that govern communications with the connected DOORS Client Agent(s) hosted on participant systems, issuance of DOORS Service Commands, and DOORS Object Exchange between the participant system(s) and DOORS Web Service instantiation(s). This subsystem manages the objects actively being shared within DOORS, and any system defined hierarchical containers of objects e.g. overlays, folders, filter results, etc.; it also controls an "event horizon" simulation time service and provides information necessary to configure DOORS the Client Agent(s) and its respective SOAP/XML interface(s).
- **Translation and Ontology Management** – for definition of the common ontology schema representing the C2/C4I Vocabulary, and semantic mapping between participant systems and the common ontology. This subsystem also manages the DOORS Translation Agents in the performance of the static system developer defined [drag-n-drop] semantic mapping of meta-data or the more dynamic adaptive rule based semantic mapping of meta-data, which matches the schema of a newly registered interface to the common ontology by employing expert system concepts. Is this way, a more robust and expansive C2/C4I Vocabulary may be built over time from the resultant aggregation and subsequent reduction for each successive participant system ontology schema introduced. Finally, this subsystem performs verification and generation of DOORS Translation Agents, including their internal objects and SOAP/XML interfaces.

- **Data Persistence** – for persistence of the DOORS Web Service management information and common ontology schema, as well as the optional asynchronous storage of shared DOORS objects. DOORS may employ both relational and XML databases for persistence.

The DOORS provides a **Web Viewer** consisting of GUIs for session management (registration, publish, subscribe), administration, and semantic mapping and translation tools. A master map view based upon *BBN's OpenMap*™ allows users that neither contribute nor or possess a participant system to view *OpenGIS*™ *Consortium* compliant geo-registered information being actively shared by the DOORS Web Service. This master map view is available as either a lightweight client or from within a web browser. *The DOORS Web Service, its SOAP/XML interface, and supporting GUIs, and its basic security model for user authentication and discretionary access control are built upon WebLogic Platform*™ *from BEA Systems.*

DOORS Ontology and Semantic Mapping

An ontology provides a formal means to conceptualize, represent, and structure domain knowledge for a community of interest, and the schema for that ontology can establish the instrument to unify discourse within the domain thereby facilitating interoperable information exchange and knowledge sharing. An ontology specifies the definitions of classes, relationships, and processes in a declarative sense, and the resultant knowledge base it represents forms a vocabulary by which to describe it.

Advances in XML related technologies, including further refinement of XML Schema, RDF and RDF Schema, and DAML+OIL as depicted in **Figure 4**, have contributed powerful new tools upon which to build ontologies such as the DOORS C2/C4I Vocabulary. XML tagging, customarily used for meta-data description, is has become an increasingly popular method to provide object encapsulation of attributes and methods and derive meaning from *semantics*, i.e. construct ontological schemas for knowledge representation, express rules for axiomatic behavior, or formulate logic for deductive/inductive reasoning. Indeed, DOORS exploits semantic mapping from multiple participant data sources schemas into a DAML+OIL based common ontology for a data mediation service, and documents the translation between local participant and common ontology schemas.

DAML+OIL is a W3C® specification for the composition and management of ontologies, and builds upon RDF and XML Schema. RDF is based upon predicate calculus and graph theory and provides a semantic network of Subject-Predicate-Object *RDF triplet* statements [*Resource* has *Property* with *Value*], a useful syntax for the development of a hierarchical object model within DAML+OIL (similar in nature to that of RDF Schema) and contributes the bounds of the vocabulary's domain and range. DAML provides description logic to reduce semantics into computable taxonomies, defines classes and properties, reinforces domain, range, and cardinality, and enhances machine readability. OIL adds reasoning by stating sufficient and necessary conditions for belonging or exclusion. Unified and revised, DAML+OIL provides rich modeling primitives, incorporates XML Schema data typing, and separates object from data type instances via

exclusive membership rules. OWL, the Web Ontology Language, is another refinement of DAML+OIL under consideration by the W3C® that could find its way into future DOORS development activities.

In composing the DOORS common ontology, a knowledge representation schema was formed that encompasses generally accepted and widely adopted source schemas from the C2/C4I domain. **Figure 5** illustrates broad categories of operational objects (symbols, messages, objects, relational entities, etc.) and their respective standards represented within this ontology. For example, Joint Common Database (JCDB) battlefield objects (BFOs) form the core set of relational DOORS operational objects.

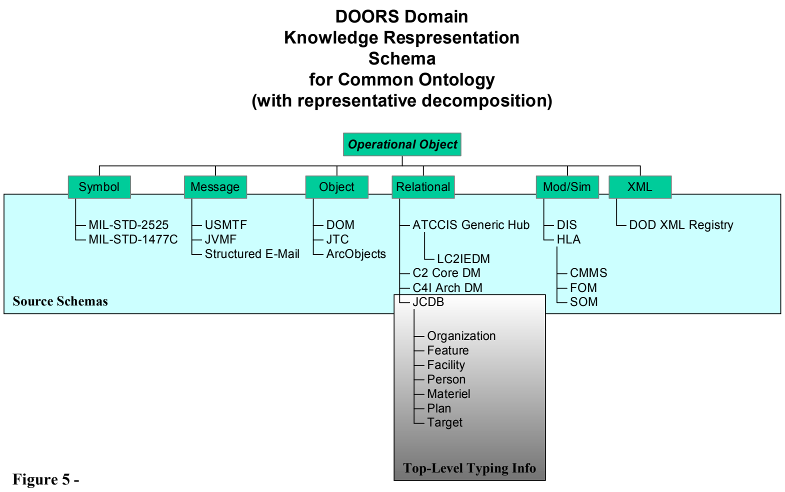


Figure 5 -
"The DOORS Domain Knowledge Base Hierarchy"

As adopters of DOORS add their system-specific schema maps to the Translation and Ontology Management subsystem in the process of creating DOORS compliant interfaces to participant systems, it is also possible the common ontology describing the DOORS C2/C4I Vocabulary lacks the structure to sufficiently describe a concept that is important to the participant system and the C2/C4I domain in general. In such cases the structure may be added to the common ontology. In this way, more robust and expansive C2/C4I Vocabulary may be built over time from the resultant aggregation and subsequent reduction for each successive participant system ontology schema introduced.

Figure 6 depicts the semantic mapping between two subject knowledge bases used by operational C2 systems involved in the DOORS operational prototype: the Global Command and Control System's (GCCS) Common Operational Picture (COP) Track Database Manager (TDBM) and the Army Battle Command System's Common Tactical Picture (CTP).

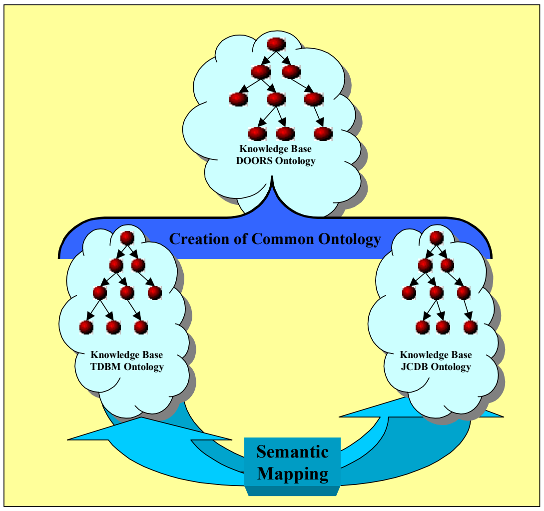


Figure 6 -
"Semantic Mapping for Ontology Mediation/Schema Translation"

Semantic mapping allowed ***tracks*** from the former schema to be translated into ***organizations*** in the latter schema by way of DOORS Translation. Semantic mapping defines how to transform source ontology schemas into the DOORS common ontology schema. XSLT has been employed for parsing schema elements and mapping translations. Generally, these mappings are constructed according to schema element type (object class, data types), cardinality (one-to-one, one-to-many, many-to-one), condition (specified value, Boolean True/False, etc.), or customized translation which applies some function operating on the participant system schema to reconcile it with concepts expressed in the common ontology. Mapping of DAML+OIL classes and properties use rules templates of RDF triplets. XPath expressions identify actual element values, which are mapped into subject/object classes contained in the ontology. Term mapping distinguishes ***containerTank*** from ***weaponTank***, and so forth. After validation of domain and range values occurs, a DOORS Translation Agent provides a SOAP/XML interface to a DOORS Client Agent, enacting the interface between a participant system and the DOORS Web Service. **Figure 7** demonstrates a very simple case of semantic mapping between a participant system's ***rectangle*** object and the DOORS common ontology primitive ***somRectangle***.

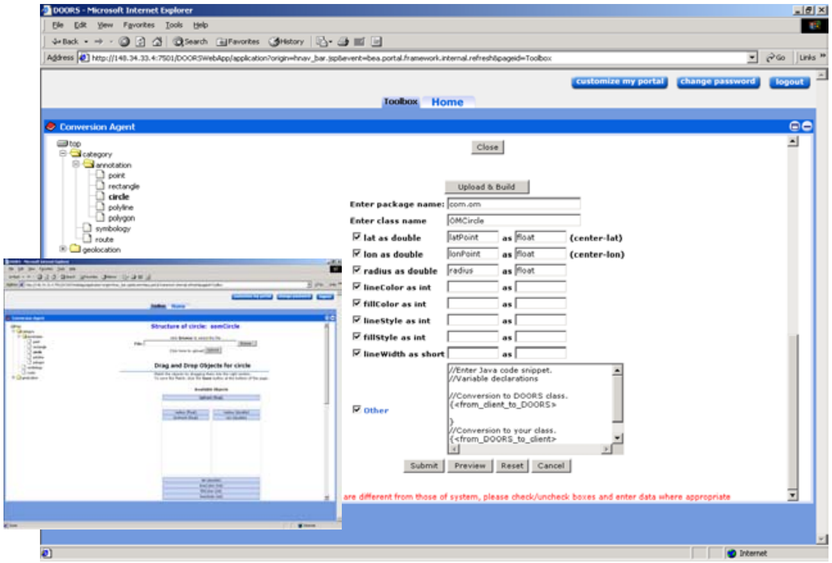
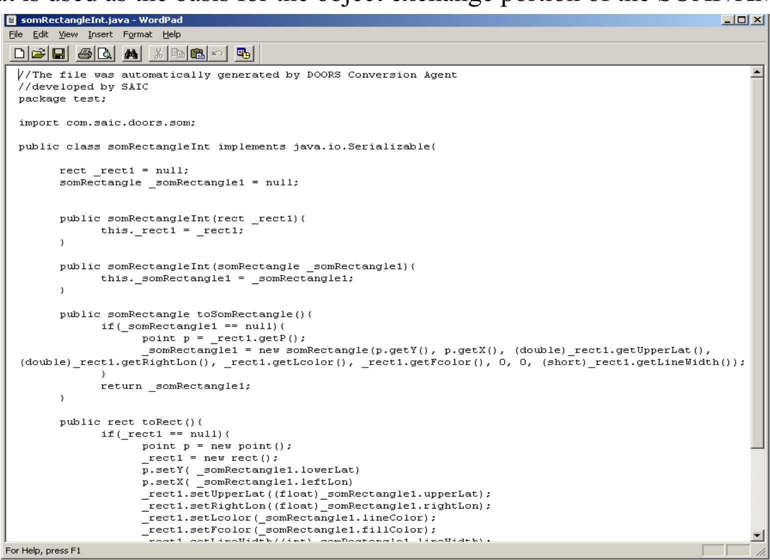


Figure 7 -
"Sample DOORS Translation Mapping"

The DOORS Web Service provides simple GUIs for static semantic mapping by experienced system developers [i.e. they are not intended for operators, but for systems or software engineers]. The completion of the mapping process is signified by submission of the map to the DOORS Translation Agent, which makes use of expert system techniques for code generation, constructing the serializable package as shown in **Figure 8** that is used as the basis for the object exchange portion of the SOAP/XML interface.



```
//The file was automatically generated by DOORS Conversion Agent
//developed by SAIC
package test;

import com.saic.doors.som;

public class somRectangleInt implements java.io.Serializable{

	rect _rect1 = null;
	somRectangle _somRectangle1 = null;


	public somRectangleInt(rect _rect1){
		this._rect1 = _rect1;
	}

	public somRectangleInt(somRectangle _somRectangle1){
		this._somRectangle1 = _somRectangle1;
	}

	public somRectangle toSomRectangle(){
		if(_somRectangle1 == null){
			point p = _rect1.getP();
			_somRectangle1 = new somRectangle(p.getY(), p.getX(), (double)_rect1.getUpperLat(),
(double)_rect1.getRightLon(), _rect1.getLcolor(), _rect1.getFcolor(), 0, 0, (short)_rect1.getLineWidth());
		}
		return _somRectangle1;
	}

	public rect toRect(){
		if(_rect1 == null){
			point p = new point();
			_rect1 = new rect();
			p.setY( _somRectangle1.lowerLat)
			p.setX( _somRectangle1.leftLon)
			_rect1.setUpperLat((float)_somRectangle1.upperLat);
			_rect1.setRightLon((float)_somRectangle1.rightLon);
			_rect1.setLcolor(_somRectangle1.lineColor);
			_rect1.setFcolor(_somRectangle1.fillColor);
```


Figure 8 -
"Sample DOORS Translation Agent Code Generation"

The DOORS Translation and Ontology Management subsystem foresees that dynamic semantic mapping of meta-data via adaptive rule based semantic mapping of meta-data that automatically seeks maps between the schema of a newly registered participant systems and the common ontology by employing expert system concepts will provide a practical technique to build up the C2/C4I vocabulary. A variety of “best fit” scoring methods such as Bayesian reasoning, distance vectors, etc. are being employed with great success in this area, leaving the systems developers to deal with only outlying mismatches rather that manually map entire knowledge bases.

RESULTS

A DOORS operational prototype was successfully demonstrated during the Joint Warfighter Interoperability Demonstration of 2002, featuring the exchange of overlay related objects between an early release version of Integrated C4I System Framework (ICSF) based Common Operational Picture being incorporated into the Defense Information System Agency’s GCCS-Joint 4.x, and the Joint Mapping Toolkit (JMTK) based Common Tactical Picture (CTP) found in the Army Battle Command System 6.x. A DOORS NCES instantiation was hosted on the Coalition Wide Area Network (CWAN) located in the Advanced Information Technology Services – Joint Program Office in Arlington, Virginia; the ICSF GCCS-COP was located with the Joint Forces Maritime Component Commander (JFMCC) at Space and Naval Warfare (SPAWAR)/San Diego, California and the JMTK ABCS-CTP was located with the Joint Forces Land Component Commander (JFLCC) at NSWC/Dahlgren, Virginia as part of a Brigade Tactical Operation Center’s (BDE TOC) complement of Maneuver Control System (MCS) platforms.

Using straightforward GUIs like those in **Figure 9**, JWID operators were able to collaborate between sites using shared overlay graphics thereby fulfilling the goals of the JWID Mission Scenario Event List (MSEL) and JWID interoperability objectives. DOORS provided the ability to share the BDE TOC *blue and red pictures* with the JFLCC and then coordinate with the JFMCC in the conduct of joint task force operations. DOORS supplied the mechanism to exchange interoperable information that reflected the commander’s information exchange requirements, contributing BDE level battlefield graphics and unit information to GCCS, a feat not able to be accomplished with the neither current production tested nor fielded system baselines. Currently, the Army interface with joint systems is limited to the data that is translated from the Global Command and Control System-Army (GCCS-A) into the JCDB and vice versa. The COP-CTP integrated picture is currently not fully realized between the GCCS-COP and the ABCS-CTP, because not all of the data representing the CTP extracted from the JCDB are capable of storage within the COP and its TDBM for viewing on GCCS-COP. In addition, the current implementation of messaging is limited, and the fidelity of data provided via the messaging applications does not represent the totality of what is available.

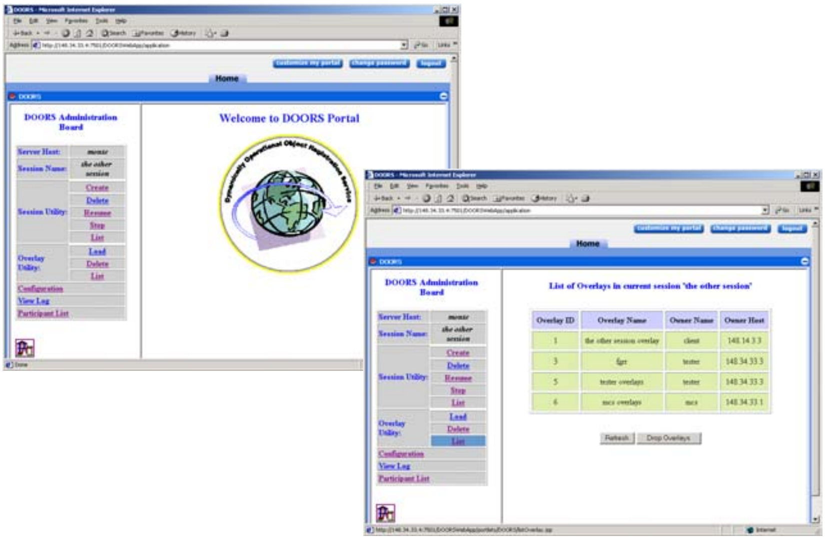


Figure 9 -
"DOORS Object Exchange and Registration Management GUIs"

Figure 10 displays a sample ABCS-CTP map overlay provided by an MCS operator that was registered and published via the DOORS Web Service.

Comment: Bonus Points for those who get the operational mistake here….

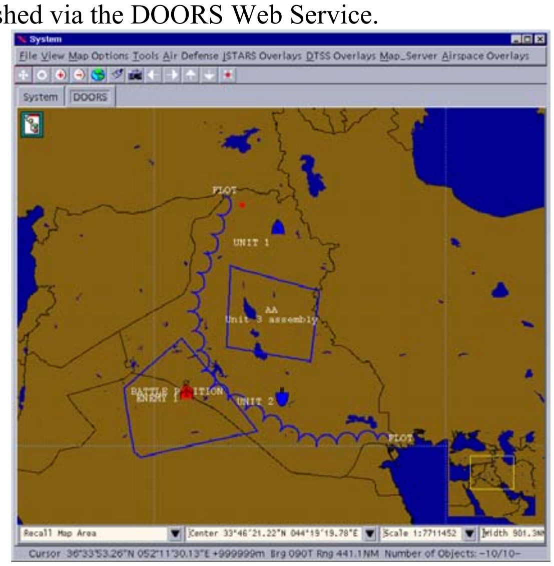


Figure 10 -
"DOORS Shared Objects Displayed on the Army Battle Command System (ABCS) Common Tactical Picture (CTP)"

Figure 11 displays the resulting overlay on the ICSF GCCS-COP infrastructure. Apart from local rendering capabilities of the mapping software, the overlays are identical, and provide shared knowledge suitable for collaboration between geographically separated operators. Using the Defense Collaboration Tool Suite (DCTS), the JWID operators to

Comment: Note that ICSF cannot properly render the FLOT curves

efficiently created courses of action to conduct military operations based upon an expanded common operational picture.

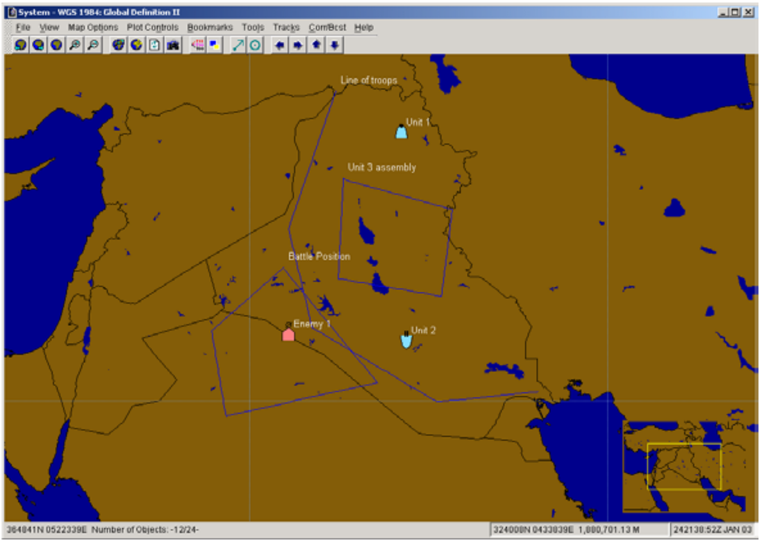


Figure 11 -
"DOORS Shared Objects Displayed on the Global Command and Control System (GCCS) Integrated C4I System Framework (ICSF)"

The following table summarizes some of the key design goals, technical approaches, and results of the DOORS technical approach:

Design Goal	**Technical Approach**	**Results/Comments**
Reduce N^2 interfaces	Data mediation via schema mapping and translation DOORS Web Service gateways available within the NCES GIG	Reduction $N^2 \Rightarrow N$ Semantic Mapping into a common ontology, and the refinement of thereof allow evolving knowledge representations and standards to be captures in one logical repository
Provide geo-referenced interoperable information	Translation Agents provide common conversion utilities for geo-referenced information to maintain a single, integrated view of the battlespace	Successfully shared overlays between GCCS-COP and ABCS-CTP
Ease the introduction of new participant system interfaces	Simple GUIs for drag-n-drop schema mapping and translation into a common ontology	Systems developers are able to rapidly create interfaces that connect their participant system(s) to DOORS, allowing system operator to collaborate using their native system representations

	Code generation of semantic maps into Translation Agent base objects and SOAP/XML interfaces	Isolates software development resources spent of interface creation and maintenance Allows for the preservation of valuable system resources, extending the life of legacy systems by making them interoperable within the GIG
Eliminate local-to-local vocabulary mismatch or interoperability fissures	Semantic Mapping between knowledge bases using XML Schema, RDF, DAML+OIL based ontology for C2/C4I Vocabulary building Translation Agent code generation of schema mapping	Seamless interoperable information is able to be exchanged end-to-end amongst DOORS compliant systems System developers needn't migrate legacy system architectures to new standards but create interoperability gateways, isolating themselves from baseline changes DOORS may be employed as a ***baseline gateway*** within the context of one system, providing a smooth transition between versions
Provide commander's information exchange requirements	DOORS compliant interfaces register, publish, and subscribe to interoperable information according to commander's intent	SOAP/XML interfaces and Translation Agents proved successful in the exchange of objects between GCCS-COP and ABCS-CTP based upon operator's object exchange selection via overlay sharing.
Provide a loosely coupled interface	DOORS Client Agents employ SOAP/XML to interface with the DOORS Web Service	Eliminates the problems of tightly coupled IPC mechanism in lossy network environments, etc.
Minimize bandwidth and promote reliable delivery	DOORS Client Agents employ SOAP/XML to interface with the DOORS Web Service	DOORS uses the publish-subscribe metaphor to advertise the availability of new object exchange information instead of polling, eliminating the number and size of inter-process communications. DOORS Client Agents actively retrieve information based upon notification rather than a pure push mechanism

Key Benefits

DOORS addresses the Joint requirement for geo-registration capability documented in Joint Requirement GRID # 741, and fulfills the joint mission need to have a geo-registered object sharing capability to support situational awareness and collaborative

planning among disparate systems in a collaborative environment. Through use of a geo-referenced/collaborative object/overlay sharing and mediation service (such as DOORS), leveraging the NCES infrastructure publish/subscribe synchronization capability on the GIG, the complete view of the battlespace ionosphere would be extended to all echelons and integrate any participant system.

SAIC's Dynamic Operational Object Registration Service (DOORS) was developed in the anticipation that a properly conceived C2/C4I vocabulary of domain knowledge representation, supported by an ontology-driven adaptive system, and employing meta-data based translation services (mapping of data from each participating system to a common representation) will provide the requisite basis for a network-centric enterprise data mediation service that addresses current interoperability challenges. DOORS provides a mechanism to exchange interoperable information for joint/combined task force operations according to a register-publish-subscribe metaphor that reflects the commander's information exchange requirements. DOORS populates the network with precise, well-structured information allowing for the rapid retrieval of tagged and staged operational object content that facilitates interoperability. Warfighters employing DOORS in the conduct of joint and coalition task force or inter-governmental agency operations supporting homeland security will effectively interoperate with other DOORS compliant systems, even those that possess disparate mapping/visualization and information management infrastructures, resulting in information superiority via the exchange of interoperable information and shared knowledge -- available to multiple levels and nodes bases upon need and choice. This level of interoperability is critical for geo-spatially and temporally registered *operational object* information that comprise the situation awareness and understanding aspects of a common operational picture, including support for "drill down" information as well. DOORS supports the type of robust data exchange and rapid integration via plug-n-play capabilities that characterize a "power to the edge" NCES. DOORS promotes an innovative, integrated, and elegant solution to the interoperability of C2/C4I systems residing within the NCES GIG.

OTHER APPLICATIONS

DOORS can be applied to as a candidate component solution in the following applications:

- As a homeland security data mediation service promoting inter-governmental agency interoperability.
- As a coalition data mediation service as well as a joint NCES infrastructure component.
- As a "system type" gateway to interface operational C2/C4I systems with systems designed for modeling and simulation (M&S), testing, training, etc.
- As a baseline migration utility, mediating data between versions of the same system.

Potential measures of effectiveness and measures of performance for the proposed ACTD include:

1. Accuracy of translation between information representations between participant systems, including geo-registered location and temporal information
2. Ability to fuse common, relevant operational pictures between multiple participant systems with disparate mapping and information management infrastructure components
3. Ability to exchange common attributes representing amplifying information related to situational awareness
4. Ability to translate message into overlay
5. Propagation latency between users' participant systems, i.e., map rendering to map rendering across the network
6. Simultaneous accommodation of publish/subscribers bounded by an established DOORS Service workspace session within the network
7. Scalability of DOORS Service and workspaces within the network; that is, integration of the Service via multiple servers and NCES dissemination/replication mechanisms

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